

# OKLAHOMA TORNADOES, MAY 1, 1954

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## INTRODUCTION

During the afternoon and early evening of May 1, 1954, thirteen confirmed tornadoes raked across Oklahoma. Official severe storm data lists two persons killed as a direct result of tornadoes and two more by drowning in floodwaters. Ninety-one people were injured. Destruction and damage to property and crops mounted to an estimated \$3,353,000. This figure includes damage by numerous hail and windstorms; hail stones ranged up to "golf ball" size and winds up to 90 miles per hour. A few tornadoes occurred in northern Texas and southern Kansas, but are not included in this report because of the absence of final data at the time of writing. The location of tornadoes in Oklahoma is shown in figure 1.

## GENERAL LARGE SCALE FEATURES

Some of the more important synoptic features that preceded the tornadoes are as follows: A surface frontal wave was near the northern Minnesota border early on the 29th of April. Following northeastward movement of this wave, very cold air advanced southward over the Central Plains. During the 30th, another wave advanced eastward across the Plains permitting the second surge of cold air to penetrate southward as far as northern Texas (fig. 2). Both of these waves were accompanied by tornado outbreaks throughout the Midwest. Some 48 hours prior to the occurrence of the tornadoes of May 1, there was a very sharp northwesterly jet at 500-mb. over California with the maximum wind speed over the northern portion of the State. This was still evident during the morning of the 30th (fig. 5). Associated with this jet and the northwest-southeast tilt of the 500-mb. trough was surface cyclogenesis over Nevada (fig. 2). The importance of this tilt and wind structure for development of storminess over the lower and mid-latitudes was pointed out by the Olivers [1].

The surface Low formed by this cyclogenesis was rather complex. It progressed eastward across the southern Rockies during the night of the 30th and the morning of the 1st (fig. 3). Meanwhile, the jet stream was being translated eastward from California into Nevada and the maximum winds were being observed in the trough (fig. 6). During the late morning of the 1st, the surface Low was

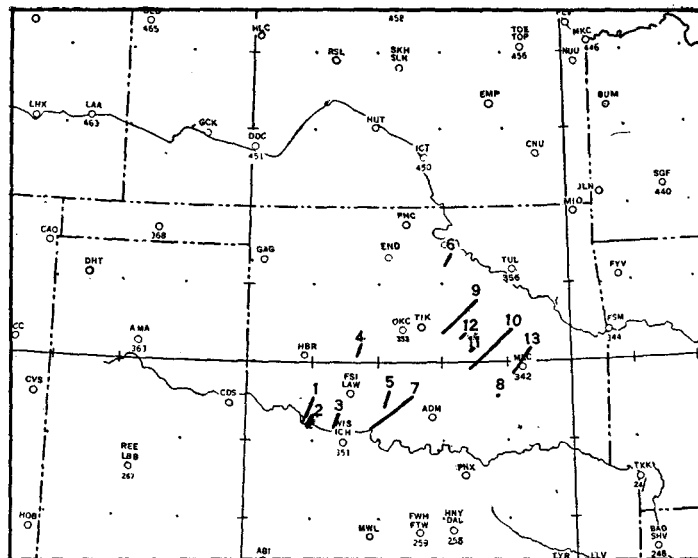


FIGURE 1.—Oklahoma tornadoes on May 1, 1954 (May 1-2 GMT): 1. 2010-2230, 2. 2130, 3. 2200, 4. 2250-2255, 5. 2330-0530, 6. 2342-2358, 7. 2345-0030, 8. 0000, 9. 0000-0120, 10. 0000-0210, 11. 0015, 12. 0105-0110, 13. 0120-0220.

becoming well organized over eastern New Mexico. This organization, along with the isallobars and the upper air pattern indicated rapid east-northeast movement. Other features of interest were the nearly steady pressures along the east coast and the slow anticyclogenesis just to the northwest of the Dakotas. Figures 4 and 7 show the surface and 500-mb. charts near the conclusion of the tornado activity. The surface Low had moved into south-central Oklahoma and the strong winds on the 500-mb. chart had moved through the trough.

## SMALLER SCALE FEATURES

Surface sectional charts have been prepared for 3-hourly intervals on the 1st until near the time of the first tornado occurrence and for one-hourly intervals during the time of most of the tornado activity. Isobars on the charts of figures 8 through 16 were originally drawn for 1-mb. intervals but only every third isobar is reproduced here for clarity. Vertical cross sections (not reproduced) were drawn to support the frontal analyses. Important features to be noted are the advance of the warm front over southeastern Oklahoma and acceleration of the cold front

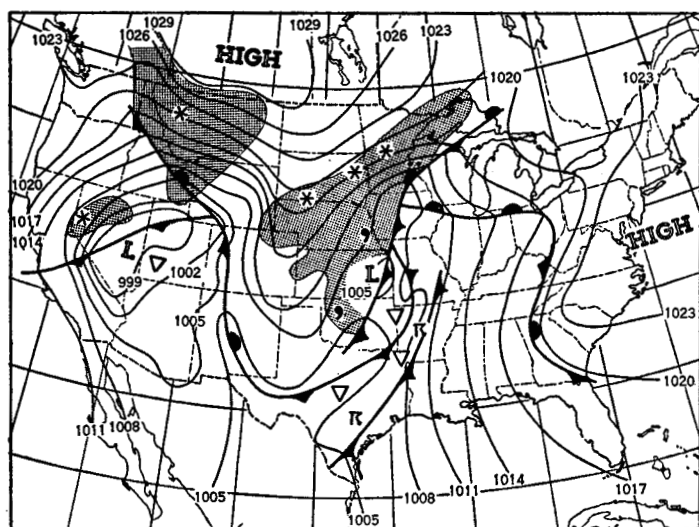


FIGURE 2.—U. S. surface chart, 1530 GMT, April 30, 1954.

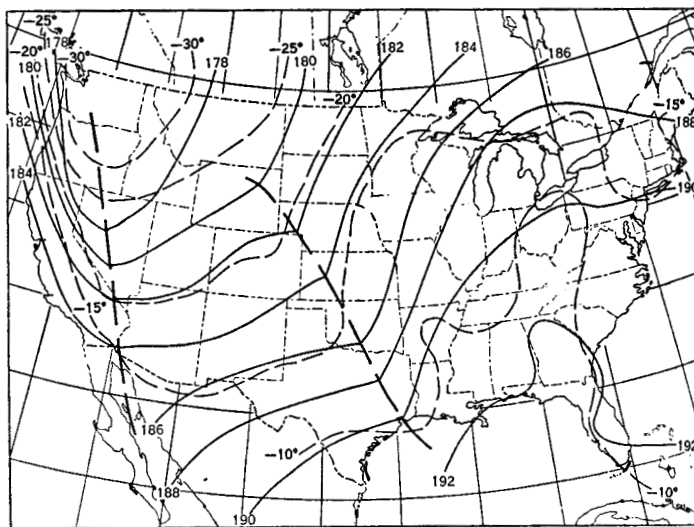


FIGURE 5.—U. S. 500-mb. chart, 1500 GMT, April 30, 1954.

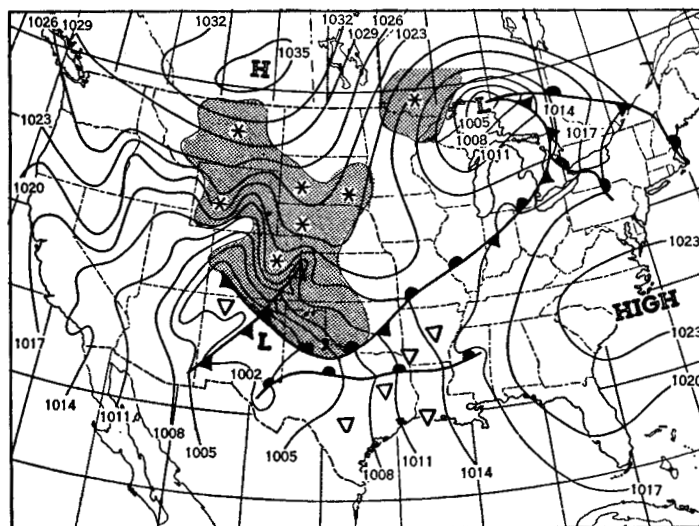


FIGURE 3.—U. S. surface chart, 1530 GMT, May 1, 1954.

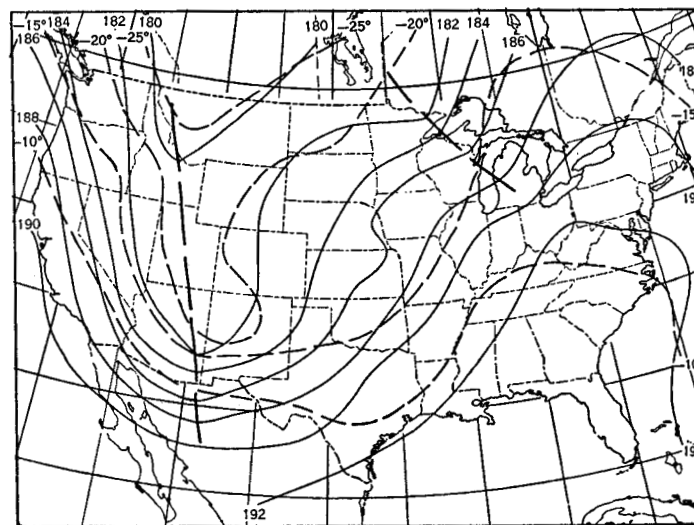


FIGURE 6.—U. S. 500-mb. chart, 1500 GMT, May 1, 1954.

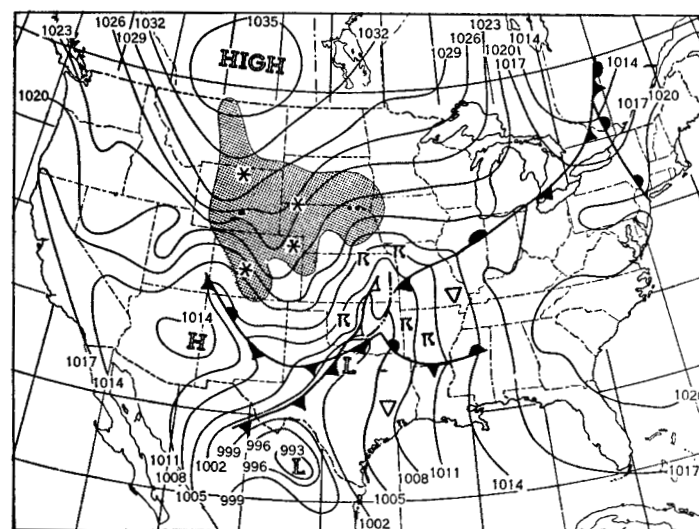


FIGURE 4.—U. S. surface chart, 0330 GMT, May 2, 1954.

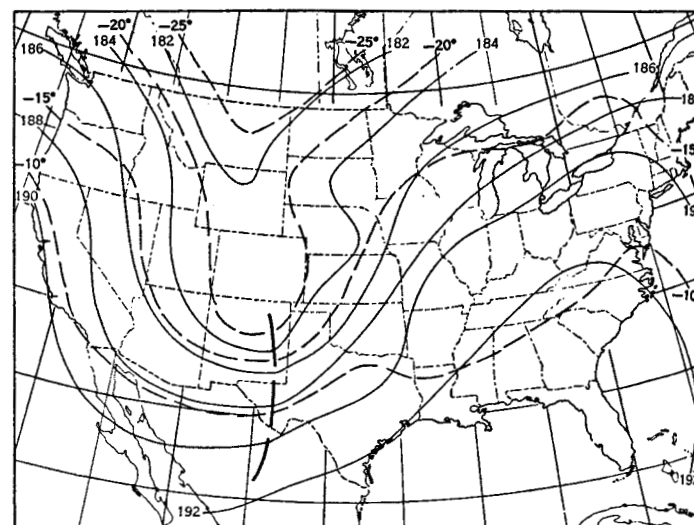


FIGURE 7.—U. S. 500-mb. chart, 0300 GMT, May 2, 1954.

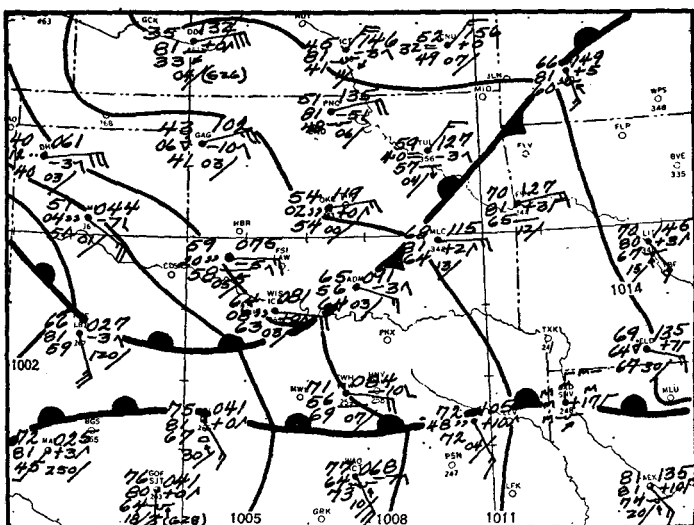


FIGURE 8.—Surface chart, 1530 GMT, May 1, 1954.

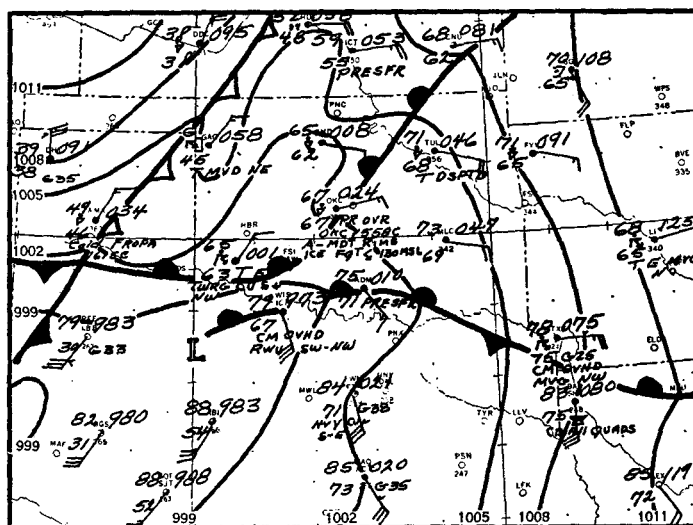


FIGURE 11.—Surface chart, 2230 GMT, May 1, 1954.

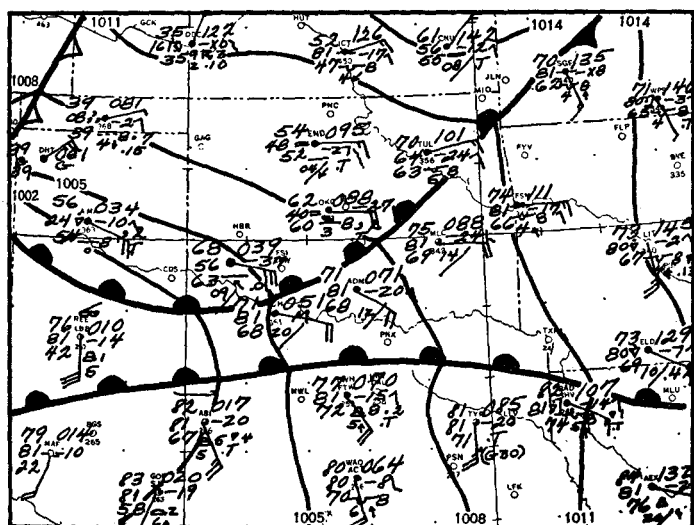


FIGURE 9.—Surface chart, 1830 GMT, May 1, 1954.

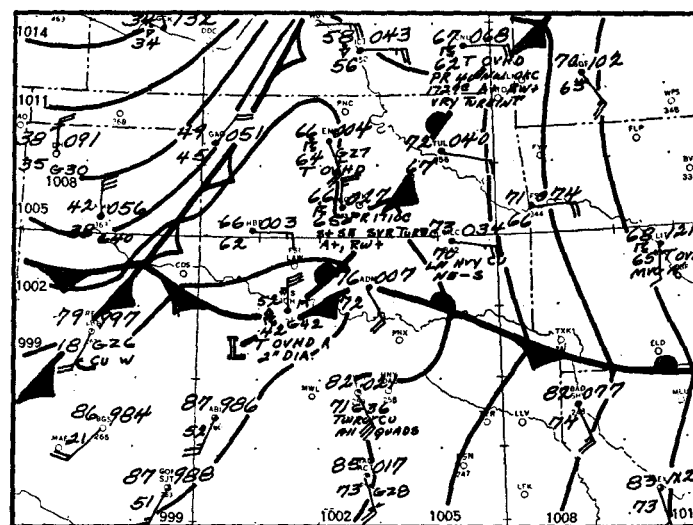


FIGURE 12.—Surface chart, 2330 GMT, May 1, 1954.

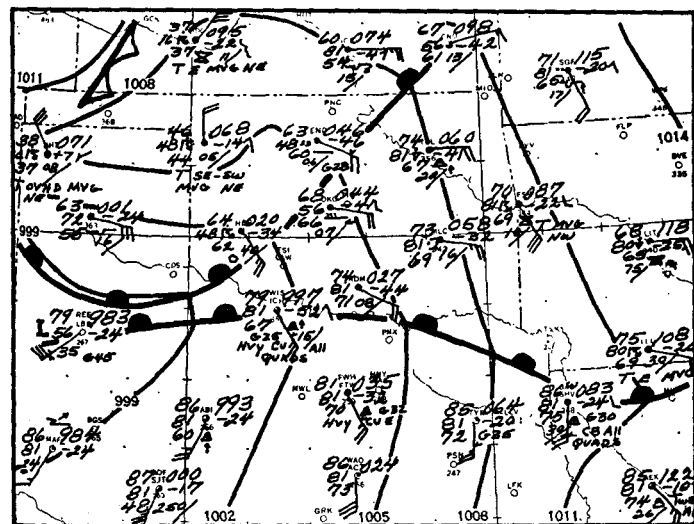


FIGURE 10.—Surface chart, 2130 GMT, May 1, 1954.

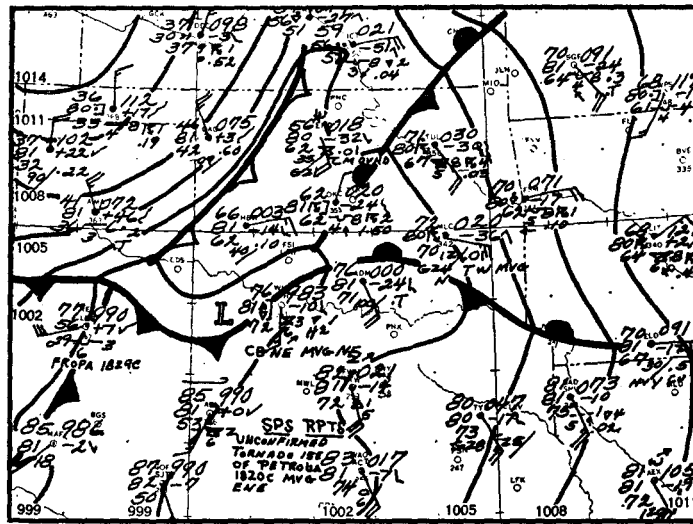


FIGURE 13.—Surface chart, 0030 GMT, May 2, 1954.

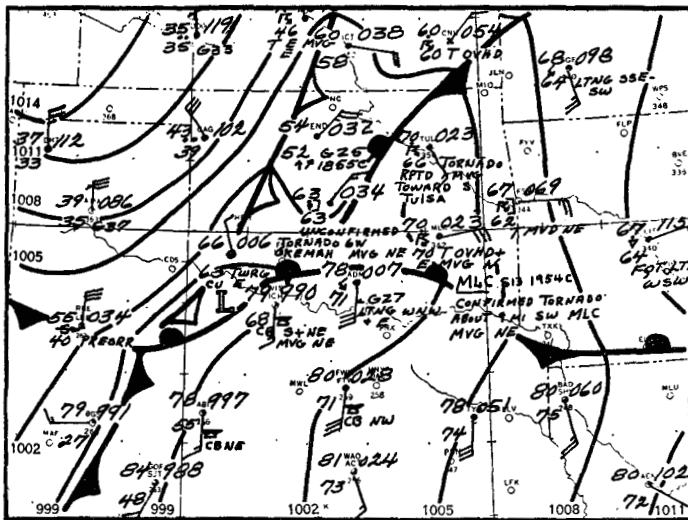


FIGURE 14.—Surface chart, 0130 GMT, May 2, 1954.

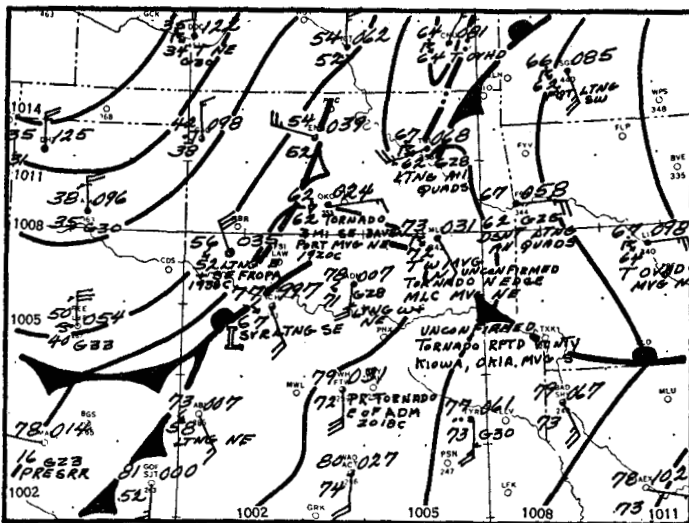


FIGURE 15.—Surface chart, 0230 GMT, May 2, 1954.

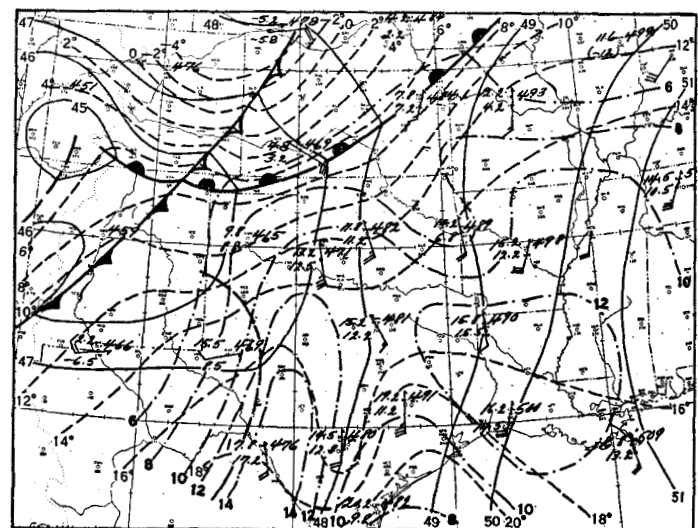


FIGURE 17.—850-mb. chart, 1500 GMT, May 1, 1954.

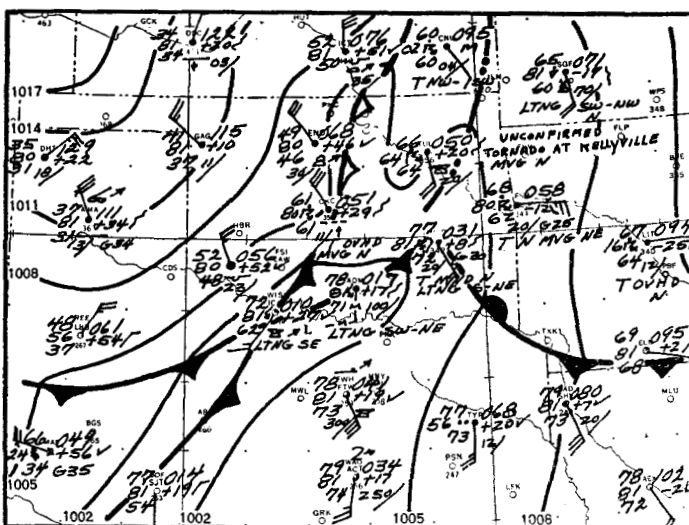


FIGURE 16.—Surface chart, 0330 GMT, May 2, 1954.

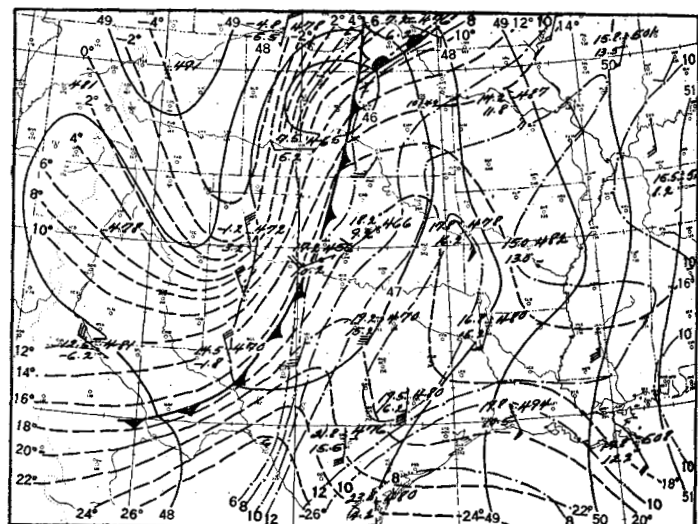


FIGURE 18.—850-mb. chart, 0300 GMT, May 2, 1954.

over western Texas. This acceleration began over New Mexico around 1830 GMT. It was found that the tornadoes occurred along or near the warm front advancing over southeastern Oklahoma and the stationary front that extended northeast-southwest through central Oklahoma. Evidence of a north-south non-frontal squall line intersecting these fronts was so weak that agreement on its location was not reached by the authors until 0230 GMT, after occurrence of most of the tornadoes. It is not meant to imply here that short squall lines or "squall-line segments" were not associated with some or all of the tornadoes. Perhaps an examination of all radar reports from the area would disclose such lines.

The 850-mb. chart at 1500 GMT (fig. 17) showed marked warm air advection over Oklahoma. There was also a tongue of warm and very moist air over southwest Texas. The importance of these features in thunderstorm, instability line, and tornado forecasting has been discussed in

considerable detail by various authors including Means [2], Crawford [3], Fulks [4], Fawbush, Miller and Starrett [5], and Armstrong [6]. The tornadoes began about midway between the times of figure 17 and figure 18; and it appears that they occurred in the warm tongue, the western portion of the moisture ridge, and west of the low level jet. Considerable data were available at 2100 GMT to substantiate these conclusions.

Coupled with the strong warm, moist air advection in the low levels over Oklahoma was warm air advection to great heights as indicated by the 500-mb. charts (figs. 19 and 20). The magnitude of the warm air advection over Oklahoma preceding the tornadoes on May 1 is shown by the 1000 to 500-mb. thickness pattern (figs. 21 and 22). The strongest warm air advection, as shown by the 1000–500-mb. thickness lines and 700-mb. contours, appeared just southwest of Oklahoma City at 1500 GMT (fig. 21); by 0300 GMT (fig. 22) it had moved through Oklahoma into western Missouri just ahead of the area where tornadoes had occurred.

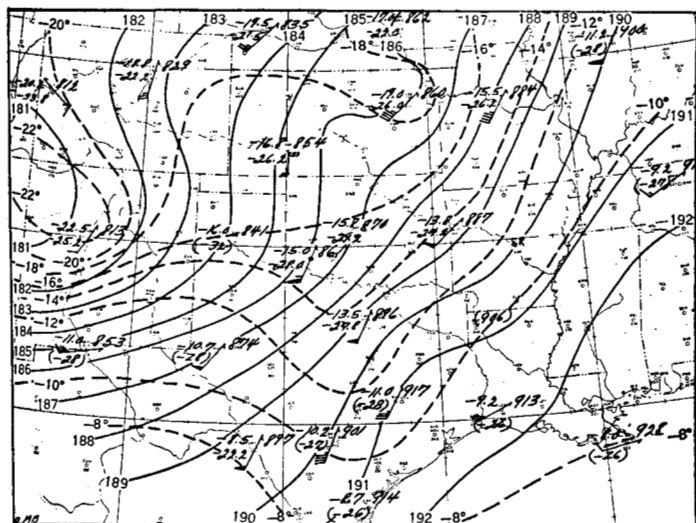


FIGURE 19.—500-mb. chart, 1500 GMT, May 1, 1954.

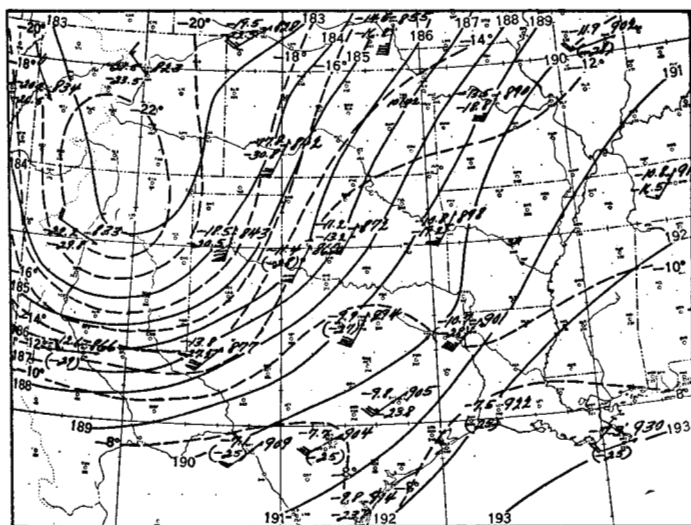


FIGURE 20.—500-mb. chart, 0300 GMT, May 2, 1954.

In connection with the thickness chart, Mook [7] points out that in many multiple tornado outbreaks the 18,600-ft. thickness contour roughly parallels the track of tornadoes. It is interesting to note that on May 1 the 18,600-ft. contour moved over the area close to the time of the tornado occurrences.

### THERMODYNAMICS

The method of radiosonde analysis is explained in Appendix I. The results of the analysis are shown in figures 23 and 24. A broad moist tongue with mixing ratios above 8 gm./kg. in the lower 5,000 ft. lay south and east of a line through western Texas, northern Oklahoma, southern Missouri, and central Illinois with a steep moisture gradient on the western side, particularly over western Texas. Low mean lifting condensation levels indicated that very little lifting was required to produce condensation in the moist tongue. Levels of free convection existed over most of the moist air and when compared

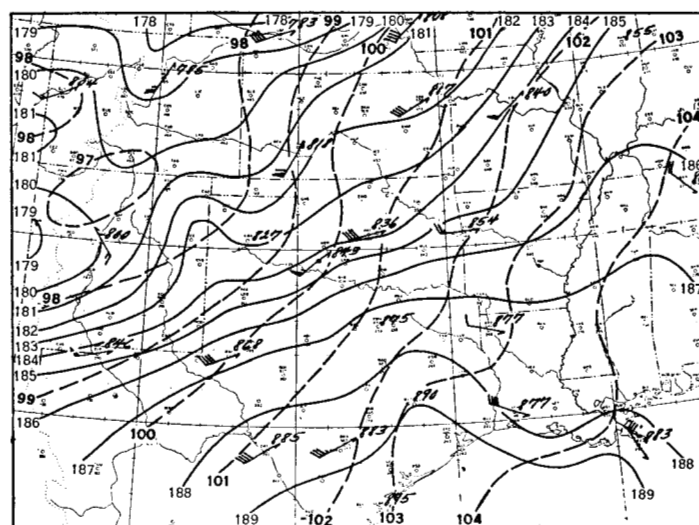


FIGURE 21.—1000-500-mb. thickness chart, (solid lines), and 700-mb. contours (dashed lines), 1500 GMT, May 1, 1954.

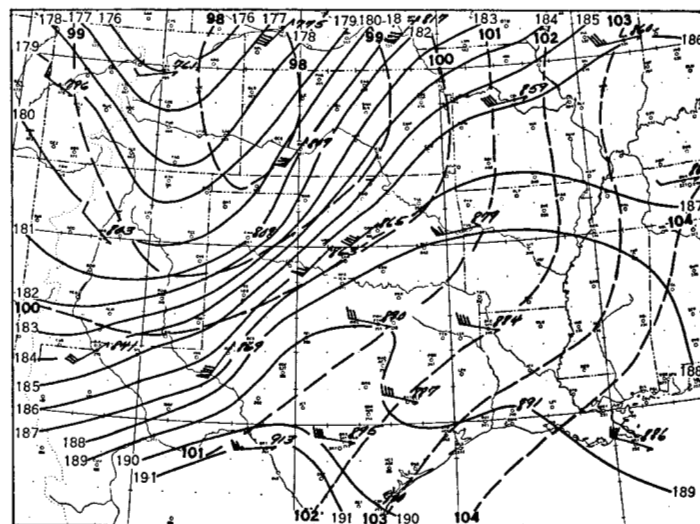


FIGURE 22.—1000-500-mb. thickness chart (solid lines), and 700-mb. contours (dashed lines), 0300 GMT, May 2, 1954.



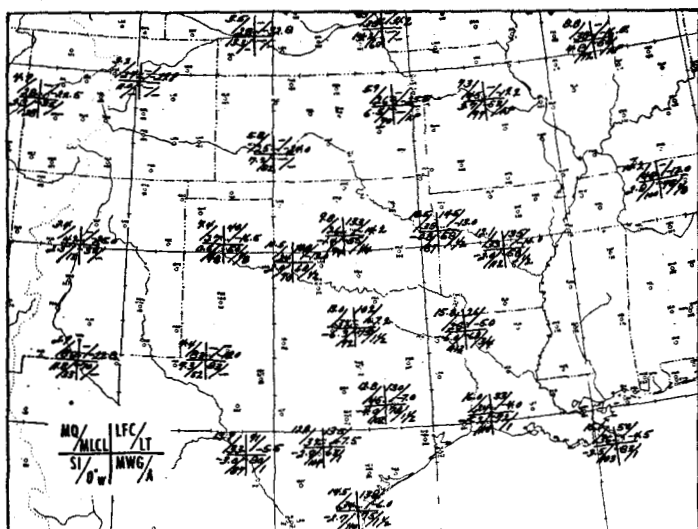


FIGURE 23.—Radiosonde analysis chart, 1500 GMT, May 1, 1954. MQ = mean mixing ratio of the lower 5,000 feet; MLCL = mean lifting condensation level of the lower 5,000 feet; LFC = level of free convection; LT = lifted 500-mb temperature; SI = stability index;  $0^\circ w$  = height of the  $0^\circ\text{C}$ . wet bulb temperature above the ground; MWG = forecast maximum wind gust; A = forecast hail size.

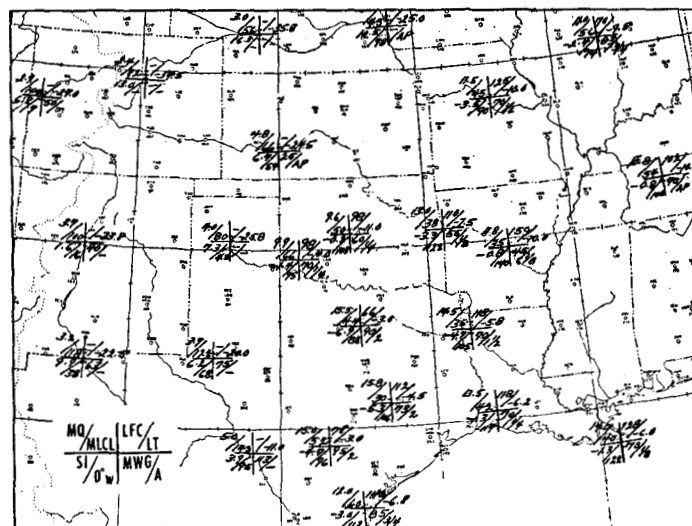


FIGURE 24.—Radiosonde analysis chart, 0300 GMT, May 2, 1954. MQ = mean mixing ratio of the lower 5,000 feet; MLCL = mean lifting condensation level of the lower 5,000 feet; LFC = level of free convection; LT = lifted 500-mb temperature; SI = stability index;  $0^\circ w$  = height of the  $0^\circ\text{C}$ . wet bulb temperature above the ground; MWG = forecast maximum wind gust; A = forecast hail size.

with the mean lifting condensation levels indicated the size of the negative area that had to be overcome in order to realize free convection.

Lifted temperatures (as defined in Appendix I) can be used as a forecast aid. When projected with the gradient winds and compared with forecast temperatures at 500 mb. a new stability field is apparent. A 6-hour stability prognosis made from the 1500 GMT data is shown in figure 25. (For details of analyzing and forecasting a stability index field, see Appendix II.) A remarkable feature brought out here is that in spite of the warm air advection over Oklahoma at high levels, as indicated by the 500-mb. chart, the inflow of warmer and more moist air in the lower 5,000 ft., as shown by the higher lifted temperatures upstream, held substantial negative stability indexes over extreme southern and eastern Oklahoma. For example, the  $-0.8^\circ\text{C}$ . stability index at Fort Smith at 1500 GMT was forecast to be  $-8^\circ\text{C}$ . by 2100 GMT. A special sounding at the verification time showed an index of  $-6^\circ\text{C}$ . By 0300 GMT (fig. 24) the index increased to  $-3.3^\circ\text{C}$ . The 500-mb. temperature of  $-13.0^\circ\text{C}$ . at 1500 GMT warmed to  $-12.5^\circ\text{C}$ . by 2100 GMT and to  $-7.5^\circ\text{C}$ . by 0300 GMT.

At 1500 GMT (fig. 23) the lowest stability indexes appeared in eastern Texas and Louisiana; but the 6-hour prognostic chart (fig. 25) forecast indexes of  $-3^\circ\text{C}$ . in extreme southwestern Oklahoma, and  $-8^\circ\text{C}$ . in southeastern Oklahoma and western Arkansas by 2100 GMT. The prognostic chart indicated a trend toward northward and northeastward movement of this very unstable air.

The heights above the ground of the  $0^\circ\text{C}$ . wet-bulb temperatures were close to the optimum values of 7,000 to 9,000 ft. for hail occurrence, according to Fawbush and Miller [8]. Calculated hail size (Fawbush and Miller

[8]) of  $1\frac{1}{2}$  to 2 inches, using the Fort Worth, Tex., sounding, was representative of the hail sizes that occurred in eastern and extreme southern Oklahoma during the afternoon and evening. Wind gusts, calculated according to Fawbush-Miller methods [9] ranged from 55 to 90 m. p. h. in the soundings surrounding eastern and extreme southern Oklahoma.

In summary, the radiosonde analysis showed a large area of moist, convectively unstable air, that with a reasonable amount of lifting would release vast amounts of energy. In other words thunderstorms with accompanying hail, windstorms, and tornadoes were to be expected in air of this type provided it could be subjected to lifting. It is necessary to look elsewhere to find the lifting mechanism.

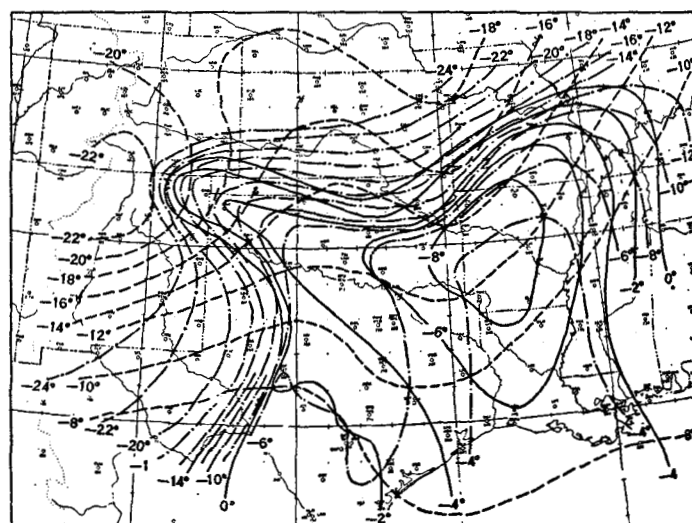


FIGURE 25.—Six-hour prognostic chart of stability index, 2100 GMT, May 1, 1954.

## THE LIFTING MECHANISM

Fawbush, Miller, and Starrett [5] suggested that the existence of an axis of high speed winds (jet) at a height somewhere between 10,000 and 20,000 ft. was important to the formation of tornadoes. Beebe and Bates [10] have considered also the jet at the 850-mb. level, and the divergence effects in the region of its intersection with the 500-mb. jet as implied by the vorticity equation. They have also taken into account the effect of a local wind speed maximum along the 500-mb. jet. Because such a maximum was not evident in the tornado area in the May 1 situation, the main emphasis here will be on the effects due to changes in curvature along the jet axes.

The upper and lower jets at 1500 and 0300 GMT are shown in figures 26 and 27. At 1500 GMT there was a splitting of the 500-mb. jet over northern Texas such that over eastern and south central Oklahoma there was advection of cyclonic vorticity, favorable for divergence aloft. The same does not apply to the westward where the left branch curved cyclonically. Along the 850-mb. jet there must have been convergence to permit the straight mostly northward flow in spite of advection of anticyclonic absolute vorticity, an effect that is the same on both sides of the jet. But in the lower levels, frictional convergence will in general be greater on the left side of the 850-mb. jet than on the right, because of cyclonic wind shear on the left side. Therefore the net result, so far as these effects are concerned, indicates the greatest upward motion was in a small area to the left of the 850-mb. jet where it crossed the right hand branch of the upper jet. This is the region where tornadoes began. At 0300 GMT (fig. 27), the maximum effect on vertical motion, according to the same arguments, was in northeastern Oklahoma and southeastern Kansas. The last of the Oklahoma tornadoes ended near McAlester (MLC) within the hour before the time of this chart, a location that is in reasonable consistency with the indications of the chart. In both figures 26 and 27, the jets were not especially well indicated by the data, but were sufficiently so that the results of the method appear encouraging.

Tepper [11] has emphasized the importance of cold front accelerations in the formation of pressure jump lines, which he relates to tornadoes. While no such line was defined (by the writers) on this day in the area, it does seem that the acceleration of the cold front through New Mexico and west Texas was important in the development simply because of the more rapid rate of replacement of the warm air by the cold. Application of Petterssen's trough formula [12] at 1830 GMT indicates acceleration at that time; it seems highly desirable that such computations be made in severe weather forecasting.

## WEATHER BUREAU FORECASTS

The forecast tornado areas, as issued by the Weather Bureau Severe Local Storm Center, Washington, D. C., in coordination with District Forecast Centers and other

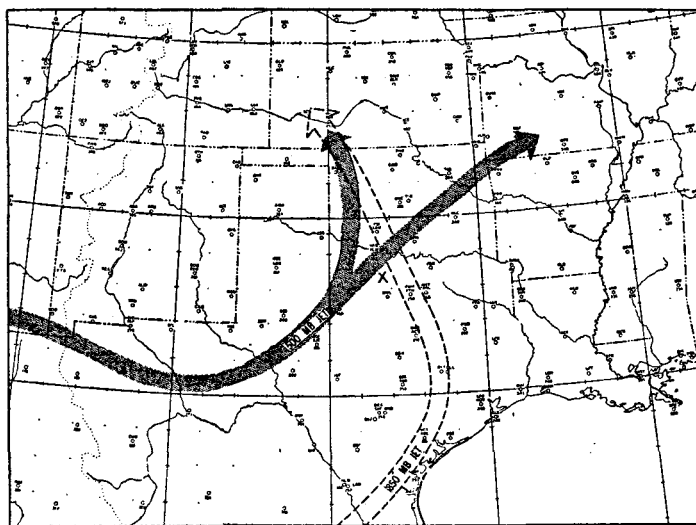


FIGURE 26.—850-mb. and 500-mb. jets, 1500 GMT, May 1, 1954.

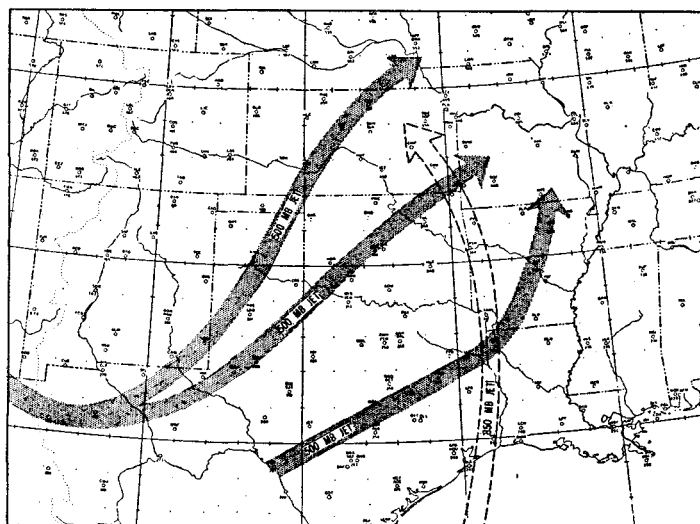


FIGURE 27.—850-mb. and 500-mb. jets, 0300 GMT, May 2, 1954.

field stations, are shown in figure 28. Severe weather forecast number 126, issued at 1550 GMT, called for tornadoes in an area along and 60 miles either side of a line from 40 miles north of Lubbock to Childress, Tex. from 1700 to 2300 GMT. Forecast number 127, issued at 1925 GMT cancelled this area and called for tornadoes along and 50 miles either side of a line from 40 miles east of Childress to 70 miles southeast of McAlester, Okla., effective 1925 GMT to 0130 GMT. Forecast number 128, issued at 2226 GMT, extended the area in number 127 to include Oklahoma east of a line 40 miles northwest of Lawton to 55 miles north of Tulsa between 2230 and 0300 GMT. Forecast number 129, issued at 0128 GMT, consolidated 127 and 128 into a new forecast area extending from a line 30 miles southeast of Wichita Falls, Tex., to 60 miles north of Wichita, Kans., eastward to the Kansas-Missouri and the Oklahoma-Arkansas borders, from 0126 GMT to 0500 GMT. Every reported tornado in Oklahoma was within a time and area specified by the forecasts.

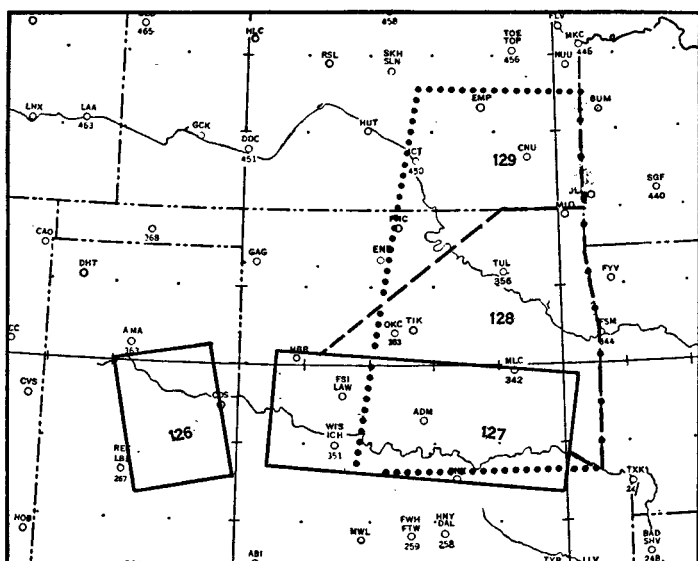


FIGURE 28.—Official Weather Bureau tornado forecast areas, May 1, 1954. See text for identifications.

The number of lives lost was few in comparison with the large amount of property damage. It is believed that timely forecasts issued by Weather Bureau stations in this area, in coordination with the District Forecast Centers and the Severe Local Storm Center, helped to prevent additional loss of life.

#### ACKNOWLEDGMENTS

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#### APPENDIX I

##### A RADIOSONDE ANALYSIS FOR SEVERE LOCAL STORM AND TORNADO FORECASTING

Severe local storm and tornado forecasting requires a



comprehensive analysis of the upper air soundings, especially in and around a possible threat area that may be outlined from the general synoptic situation. There are many ways to obtain this analysis; and it may be difficult in the end to say that one is better than the other. There are, however, certain general features that must be incorporated. Certainly, every analysis needs to include a measure of thermal stability, moisture content, and potential energy. In addition, the operation should be standardized so that a number of forecasters can go through the procedure and come out with very nearly the same answers. Time is essential in the preparation of the forecast, and the radiosonde analysis should not be so long that time is sacrificed from other equally important work. Finally, the resulting information should be plotted on a chart for ready reference and for comparison of one station with another.

A suggested type of radiosonde analysis is presented here that seems practical enough to be incorporated into the routine of daily forecasting. The first step is to draw the wet-bulb temperature curve on the adiabatic charts. It then becomes very easy to determine convective stability. Next, draw a horizontal line at a height of 5,000 ft. above the ground; the selection of this height is based on the approximate height of the mean moist layer in the Fawbush-Miller mean tornado sounding [13]. In the past, emphasis has been placed on the actual height of the low-level moist layer for computations. Often it is difficult to define a moist layer; different forecasters may choose different heights. Also, studies by Armstrong [6], Malkin and Galway [14], recent work by Fawbush and Miller [15] and Beebe [16] point out that tornadoes sometimes occur in air that is moist to very high levels. Beebe and Bates [10] and Means [17] show that moisture is carried to higher and higher levels when the air mass undergoes low level horizontal convergence. Therefore the exact height of a moist layer becomes less important. It is not intended here to discount the importance of the dry-over-moist airmass structure. It is this structure, with the inversion over the moist air, that will permit great amounts of potential energy to be stored. This is indicated by positive areas observed on the adiabatic charts with large negative stability indexes (Showalter [18]). This inversion acts as a lid to convective activity; but if removed by a lifting or "triggering" mechanism the possible generation of kinetic energy is tremendous. On the basis of thermodynamical reasoning alone it is the authors' opinion that perhaps the most severe tornadoes can be expected in air that has built up a large amount of potential energy by dry-over-moist structure before the "triggering mechanism" (such as the arrival of a squall line) begins to carry moisture high enough for it to reach the level of free convection.

A suggested model for this raob analysis is as follows:

MQ/MLCL	LFC/LT
SI/0° w	MWG/A

MQ=mean mixing ratio, in grams per kilogram, of the lower 5,000 ft. of air above the ground. MLCL=mean lifting condensation level through the lower 5,000 ft. of the sounding, in hundreds of feet above the ground, found where the mixing ratio line representing the value of MQ intersects a dry adiabat through the mean potential temperature of the lower 5,000 ft. It is believed that the MLCL is representative of the condensation level that will develop in an air mass subjected to low-level horizontal convergence or frontal lifting. Its value can be improved, when forecasting late afternoon or early evening activity, by forecasting the maximum surface temperature and using the intersection of the MQ line with the dry adiabat through the maximum temperature. LFC=level of free convection in hundreds of feet above the ground, if such a level exists, found where a pseudo-adiabat projected upward from the MLCL intersects the temperature curve. Heights are given in hundreds of feet above the ground to facilitate comparison with ceiling heights and cloud tops reported in hourly sequences. LT=lifted temperature at 500 mb. in degrees Celsius, found at the intersection with the 500-mb. level of a pseudo-adiabat projected upward from the MLCL. SI=stability index, in degrees Celsius found by subtracting the lifted temperature from the actual 500-mb. temperature. This is a slight revision of the Showalter Stability Index [18], but has essentially the same meaning. In addition, it is more conservative since mean values for a layer are used rather than values at a fixed point. 0° w=height of the zero-degree wet-bulb temperature, in hundreds of feet above the ground. The height of the zero wet-bulb temperature appears to have a definite relationship to the severity of hailstorms and possibly the occurrence of tornadoes (cf., Showalter [18]). The optimum height seems to fall around 7,000 to 9,000 ft. (Fawbush and Miller [8]). MWG=maximum wind gusts, in miles per hour, found by projecting a pseudo-adiabat downward through the 0° w to the ground, measuring the difference between the resulting temperature at that point and the surface temperature expected at the forecast time of occurrence of the thunderstorm, the maximum wind gust then to be determined from the Peak Wind Gust Graph of Fawbush and Miller [9]. A=expected hail size at the ground in inches, found by first determining the convective condensation level (intersection with the temperature curve of the mixing ratio line representing MQ), and then following the procedures of Fawbush and Miller [8] using their hail graph.

All the values on the Raob Analysis Chart are static values taken at a fixed time. The problem of projecting these values in time and space for as much as 6 to 12 hours is a most challenging one and results will be only approximate at best.

## APPENDIX II

### ANALYZING AND FORECASTING THE STABILITY INDEX FIELD

In connection with the development of severe local storm and tornado forecasting, an effort has been made to find a conservative stability index and a representative stability pattern. The stability index obtained by the Showalter [18] method uses temperature and dew point at one level, either 850-mb. or the top of the moist layer (if below the 850-mb. level), to determine a lifted 500-mb. temperature. It is proposed here to use the mean wet-bulb potential temperature of a layer of air near the surface for the same purpose. The index field may be obtained by graphical subtractions after drawing isolines of the actual and lifted 500-mb. temperatures. A 6-hour prognostic chart may be made by advecting the lifted temperature and the 500-mb. temperature with the wind streams at the gradient level and the 500-mb. level respectively.

Suggested detailed steps in the analysis are:

1. Plot the bars and shafts for the 500-mb. or 18,000-ft. wind and the gradient level wind (third group in the upper wind message, at an average height of about 2,000 ft. above ground). Plot the raob data around the station circle as follows:

TT hhh  
○  
T'T' SI

hhh=height of the 500-mb. surface

TT=500-mb. temperature

T'T'=lifted 500-mb. temperature. When forecasting for late afternoon activity the lifted temperature is based on the forecast surface maximum temperature for the day.

SI=(TT-T'T')=stability index

2. Draw the isolines:

TT for every two degrees, in red

T'T' for every two degrees, in green

SI for every two degrees in blue, obtained by graphical subtraction of the two temperature fields.

500-mb. contours in yellow for every 100 or 200 feet, especially when wind reports are scarce.

This analysis would be laborious and tedious for an area as large as the United States; however, its use is intended for smaller threat areas of severe local storm activity and it is usually sufficient to consider only areas with index values less than +4.

A 6-hour stability prognosis may be constructed as follows:

1. Project the 500-mb. temperatures downstream with about 50 percent of the 18,000-ft. or 500-mb. wind speeds, corrected for trough movements, dynamic effects, etc.
2. Project the lifted temperatures downstream with the full speed of the gradient level wind. Since the lifted temperature is based on average conditions through the lower 5,000 ft., it is a fairly conservative property, except as it is affected by diurnal temperature changes and precipitation. Adjustments may be made for frontal movements and expected change in the low level flow.
3. Obtain the forecast stability pattern by graphical subtraction. Normally areas with index values greater than +2 can be ignored. The stability index is only a measure of potential energy in the air mass; some lifting or "triggering" mechanism is needed to release the energy. This mechanism may be daytime heating, cold front action, arrival of a squall line, nocturnal cooling aloft, frictional convergence within a zone of cyclonic wind shear or a low pressure center or trough, larger scale convergence and divergence patterns favorable to general lifting, or lifting by a pseudo-cold front formed by previous thunderstorms, and other possible causes.